TITLE: COMPARISON OF ROAD FREIGHT TRANSPORT TRENDS IN EUROPE. RESULTS OF AN INPUT-OUTPUT STRUCTURAL DECOMPOSITION ANALYSIS

SUBMISSION DATE: 11/12/2014

WORD COUNT: 6,249words+ 2 figures+3 tables = 7,499words

AUTHOR'S NAMES:

Corresponding author: Ana Alises
Ph.D. Candidate
Transport Research Centre (TRANSyT)
Universidad Politécnica de Madrid
Calle Profesor Aranguren s/n, 28040 Madrid
Phone number: +34 91 336 52 59
E-mail address: ana.alises@upm.es

José Manuel Vassallo
Associate Professor
Transport Research Centre (TRANSyT)
Universidad Politécnica de Madrid
Calle Profesor Aranguren s/n, 28040 Madrid
Phone number: +34 91 336 66 55
E-mail address: jvassallo@caminos.upm.es

Mario Aymerich
Director
EIB Renewables, Energy Efficiency & Energy Networks Inter-relationships
European Investment Bank
98-100, Blvd. Konrad Adenauer. L-2950 Luxembourg.
Phone number: +352 43 79 88564
E-mail address: m.aymerich@eib.org

ABSTRACT

Decoupling road freight transport from economic growth has been acknowledged by the European Union to be a key means to improving sustainability. It is therefore important to identify the drivers that explain road freight transport demand in order to determine the most appropriate policy measures to reduce road transport without curbing economic development. This research uses an Input–Output (IO) structural decomposition analysis (SDA) to explain road freight transport in terms of a set of key variables that have strongly influenced road freight demand in recent decades in European countries. This methodological approach allows us to quantify the contribution of certain factors in each country —such as economic growth, economic structure and the evolution of road freight transport intensity (including improvements in both supply and transport systems) — to road freight transportation. The empirical basis for this analysis is a dataset of nine European countries which have IO tables and road transport data available from 2000 to 2007, comprising data on domestic production, imports and exports as well as tonne-kms for 11 types of commodity classes. The results show that aggregate road transport demand has grown –driven mainly by economic activity– but this growth has been strongly curbed in some countries by changes in road freight transport intensity and moderately by the dematerialization of the economy. As a result, different levels of decoupling can be seen across Europe.

Keywords: *Road freight transport, input-output, decoupling, Europe, structural decomposition analysis.*

INTRODUCTION

Transport is essential for economic development, but it is also responsible for a wide variety of externalities. Past trends indicate that for decades the European transport system has been moving away from sustainability and causing environmental and social problems. Specifically, in the last decade transport has accounted for around a third of all final energy consumption in European Union (EU) countries, and more than a fifth of greenhouse gas emissions. Moreover, road transport, the most energy and carbon intensive transportation mode, has become the dominant mode of transport within Europe, recording the highest share of inland freight transport in 2007 with nearly 80% tonne-kms in EU-27.

In this scenario there is an urgent need for actions aimed at reaching transport sustainability targets at both the national and European levels. The challenge, taken up by the EU, is to increase transport efficiency through the full internalization of the negative side-effects of transport *(1)*. The EU has backed a number of policy measures to reduce road freight transport-related externalities *(2)*, and one of the key tools for accomplishing this goal is to promote the decoupling of road transport growth from economic development *(3)*.

Decoupling means to undo the traditional link between economic growth and road transport activity. This concept has been widely discussed in policy reports. For instance, it was the focus of the Standing Advisory Committee on Trunk Road Assessment (SACTRA) report in the United Kingdom in 1999, and has also been addressed in political documents such as the European White Paper entitled "European Transport Policy for 2020: Time to Decide" *(4)*.

There has traditionally been a historic correlation in most countries between gross domestic product (GDP) and road transport demand. However this appears to have changed over the last few years with the emergence of two trends that have been observed in a number of countries. In some (e.g. Spain, Germany or Sweden), road freight transport has shown continued growth but at a lower rate than the growth in GDP, in a process that can be defined as relative decoupling —that is, the link between transport and the economy has been weakened. In others, like the UK, transport growth has been negative while economic growth has been positive, which could be defined as absolute decoupling —the link has been almost broken— *(5)*. Numerous works have studied these trends in the evolution of road transport demand (see e.g. REDEFINE project —*(6)*—, *(7)*, *(8)*, *(9)* and *(10)*). The approach –both when analysing a single country and when comparing the behaviour of a group of countries– has been usually to break down the road transport volume into explanatory factors. The results of these studies show that divergences between growth in GDP and growth in freight transport in some countries —that is to say, the decoupling level— are caused by differences in characteristics such as economic structure, topography, geography, size, land uses, socio-economic factors and transport infrastructure.

Most industrialized countries, like the UK, have been making the transition during last decades to more service-oriented economies, and thus their economic growth has become progressively detached from road transport demand. Other sectors such as agriculture or mining demand more tonne-kms for their production processes than service sectors. As services have expanded their share of total GDP, this has led to higher economic growth than in the transport sector *(11)*.

Transport demand derives from economic activity, and the restructuring of the economy may lead to changes in the goods produced and moved, and in transport requirements. Specifically, freight activity is driven by complex and interlinked production processes and trade relationships. Recent years have seen increasing specialization, new production organization systems such as 'just-in-time' distribution, and an ever greater concentration of manufacturing and storage *(12)*. All these factors lead to changes in transport patterns, as supply chain organization influences both transport distances and modal split *(3)*.

Road transport volumes are influenced by a wide range of factors that cause different trends across Europe. However, the importance of each one of these factors on the final demand in each country is not yet clear. This knowledge is crucial to understanding the likelihood of decoupling in the EU and of achieving sustainable development.

Explaining road freight transport volume through a sole indicator such as GDP may in some cases provide erroneous results, as this variable does not take account of all the relevant factors mentioned above. In contrast, by considering the productive structure from an Input-Output (IO) approach we can see the structural relationships of production over time. This information, along with the evolution of road transport intensity sorted by commodity —the volume of tonne-kms demanded by each economic sector in its production processes, that is tonne-kms/output— allows us to connect economic indexes such as production, economic structure, inter-sector dependences, imports and exports; and technological and logistical factors such as modal split, supply chain structures and road networks. IO models are very useful tools for analysing the relationships between sectors of the economy, the indirect impacts of changes in household expenditure patterns, and the effects of economic restructuring on transport demand.

Following this approach, the IO structural decomposition analysis (SDA) applied to road transport demand serves to explain road freight changes over time by connecting the production characteristics of a particular country with the efficiency of its road transport system. This analysis enables us to conduct a cross-country comparison to identify the variables influencing European road freight demand in the last few years, identify the countries that have achieved significant decoupling, and determine which factors have played the greatest role in decreasing road transport volume in each one.

Although IO techniques have been used in the past to develop road transport models (see e.g. *(13)*), neither this type of framework nor SDA analysis have ever been applied to explain and compare transport trends. It is worth noting that the SDA technique has already been used in studies on energy consumption (e.g. *(14)* and *(15)*) and atmospheric pollution trends (e.g. *(16)* and *(17)*), and may also be useful in explaining road freight transport trends. This paper aims to contribute to the transportation literature on this subject, and is structured as follows. In Section 2 we describe the methodology and define the components explaining road transport demand. In Section 3 we apply this methodology to some EU countries and discuss the main results. We also develop a cross-country comparison pointing out the main similarities and divergences among them while confronting our findings with previous research about this topic. Finally, in Section 4 we end with some conclusions and highlight the future research needed in this area.

METHODOLOGICAL FRAMEWORK

The Input-Output (IO) table is based on national accounting. Its mathematical structure consists of monetary transaction flows among the economic sectors of a country. In the basic IO model *(18)* interactions between both productive and purchasing sectors representing industries are characterized as an equilibrium between total supply and total demand, and can be expressed by the equilibrium equation of Leontief model $\mathrm{x} = (\mathrm{I} - \mathrm{A})^{-1}\mathrm{f}$, where x represents the production vector —that is, the total output corresponding to all sectors of the economy—, f is the final demand vector and $(\mathrm{I} - \mathrm{A})^{-1}$ is the Leontief inverse matrix [L] — which reflects the requirements of any industry supplied by sectors—.

Some of the most recent economic analyses based on an IO approach have added complementary information to the basic IO model structure to overcome the limitations of the information provided by the IO tables. Our methodological framework follows this approach in order to identify the key factors explaining road freight transport demand in each of the countries analysed. We assume that transport demand of a country depends on both production levels and productive structure, which is known trough IO data. To define completely road freight transport demand we need in addition information about the volume of tonne-kms demanded by each economic sector in its production processes— that is the road freight transport intensities (RFTI) measured in tonne-kms/output—.

Therefore, we add a vector to the conventional IO model containing road freight transport intensity by sector —from sector 1 to sector n— in each term: RFTI = $[\mathrm{RFTI}_1, \mathrm{RFTI}_2, \dots, \mathrm{RFTI}_\mathrm{n}]$.

Road freight transport intensity (RFTI) may vary across sectors and countries due to differences in certain aspects such as supply chain organisation and the evolution of road share compared to other modes *(9)*. RFTI can be expressed through several ratios. These ratios are: (a) the inverse of the average value density —that is the ratio of the average weight of goods to the monetary production value (tonne/$), which is influenced by new product design techniques, manufacturing processes, and the current tendency to use lighter materials—; (b) handling factor —referring to the number of times a product is lifted between the origin and destination in the supply chain for each type of commodity—; (c) modal split—in this case we use the data for tonnes hauled by road—; and (d) average length of haul of the journeys carried out by the hauliers of a country—which depends on the location of industrial production and storage centres and on road networks configuration.

As equation **(1)** shows, by multiplying these values we can obtain the RFTI in a certain country for sector i, that is $\mathrm{RFTI_i}$. These values may vary over time as a result of either structural or logistical changes, and thus for an accurate analysis of road transport trends, road freight transport intensity should be estimated annually for each economic sector and country.

$$RFTI_i = \frac{tonnes - km_{road,i}}{Output\ (\$)} = \\ = \underbrace{\frac{tonnes_{produced,i}}{Output_i\ (\$)}}_{inverse\ of\ value\ density} \times \underbrace{\frac{tonnes_{lifted,i}}{tonnes_{produced,i}}}_{handling\ factor} \times \underbrace{\frac{tonnes_{lifted,road,i}}{tonnes_{lifted,i}}}_{modal\ share} \times \underbrace{\frac{tonne - kms_{road,i}}{tonnes_{lifted,road,i}}}_{average\ lenght\ of\ haul} \quad \textbf{(1)}$$

According to previous definition, letting T be a vector (n x 1) that contains the road transport demand by commodity class, we can define a vector whose elements express the sectorial RFTI value :

$$RFTI = T'\hat{x}^{-1} \quad \textbf{(2)}$$

Thus, we can obtain the road transport volume in the form $\mathrm{T} = \widehat{\mathrm{RFTI}}\ \mathrm{x}$, and therefore, by using the equilibrium equation of the Leontief model $\mathrm{x} = (\mathrm{I} - \mathrm{A})^{-1}\mathrm{f}$ we define the aggregate road transport demand T according to the following equation **(3)**:

$$T = \widehat{RFTI}\ (I - A)^{-1} f = \widehat{RFTI}\ L[\,\bar{s}\sum GDP + Imp] \quad \textbf{(3)}$$

By using an annual IO table, the final demand vector can be expressed from an expenditure approach by adding the sector GDP vector and the vector of import volumes (see *(19)*)We have used that mathematical relation to express equation **(3)** and also a vector $\bar{\mathrm{s}} = (\bar{\mathrm{s}}_1, \bar{\mathrm{s}}_2, \ldots, \bar{\mathrm{s}}_\mathrm{n})$ that expresses the participation of the sector GDP in the aggregate national GDP (that is, sectorial shares of GDP of the n productive sectors), and thus we have included the global annual value of each country's GDP.

The matrix [L] and the vectors used — $t, \bar{\mathrm{s}}$ and Imp — in this transport model must reflect an identical disaggregation in the n activity branches considered. In that way, we have connected the economic behaviour expressed by the IO model together with technological and logistic factors included in the definition of RFTI.

Thus by applying the SDA technique (see a detailed explanation of that method in *20*), we are able to break down the aggregate changes in road freight transport demand in a particular economy into the contributions of five main factors, namely: (i) changes in RFTIs; (ii) variation in production linkages depending on the inter-sector relationships described by [L]; (iii) changes in GDP structure, that is to say, changes in $\bar{\mathrm{s}}$; (iv) global growth or decrease in GDP; and (v) changes in import volume. This analysis thus enables us to quantify the contributions of these five variables to the evolution of road freight transport volumes in a specific country from the base year — expressed by subscript 0 — to each one of the following years in the study period —subscript 1. That is to say, we explain $\Delta T^{0-1} = T^1 - T^0$—measured in tonne-kms— , through the following equation **(4)**, resulted from applying the decomposition theory proposed by Dietzenbacher and Los *(20)* to **(3)**.

$$
\begin{aligned}
&\Delta T^{0-1} = \\
&= \underbrace{\left(\frac{1}{2}\right)(\Delta\,\hat{t}\,)^{0-1}\left[L^0\left(\,\bar{s}^0\textstyle\sum GDP^0 + Imp^0\right) + L^1\left(\,\bar{s}^1\textstyle\sum GDP^1 + Imp^1\right)\right]}_{Road\ freight\ transport\ intensity\ change\ effect\ (\mathrm{C}^1)} \\
&+ \underbrace{\left(\frac{1}{2}\right)\left[\,\hat{t}^{\,0}(\Delta L)^{0-1}\left(\bar{s}^1\textstyle\sum GDP^1 + Imp^1\right) + \,\hat{t}^{\,1}(\Delta L)^{0-1}\left(\bar{s}^0\textstyle\sum GDP^0 + Imp^0\right)\right]}_{Production\ linkages\ effect\ (\mathrm{C}^2)} \\
&+ \underbrace{\left(\frac{1}{2}\right)\left[\,\hat{t}^{\,0}L^0(\Delta\bar{s})^{0-1}\textstyle\sum GDP^1 + \,\hat{t}^{\,1}L^1(\Delta\bar{s})^{0-1}\textstyle\sum GDP^0\right]}_{GDP\ structure\ change\ effect\ (\mathrm{C}^3)} \qquad \textbf{(4)} \\
&+ \underbrace{\left(\frac{1}{2}\right)\left[\left(\,\hat{t}^{\,0}L^0\,\bar{s}^0\right) + \left(\,\hat{t}^{\,1}L^1\,\bar{s}^1\right)\right](\Delta\textstyle\sum GDP)^{0-1}}_{GDP\ growth/decrease\ effect\ (\mathrm{C}^4)} \\
&+ \underbrace{\left(\frac{1}{2}\right)\left[(\,\hat{t}^{\,0}L^0\,) + (\,\hat{t}^{\,1}L^1)\right](\Delta Imp)^{0-1}}_{Imports\ volume\ change\ effect\ (\mathrm{C}^5)}
\end{aligned}
$$

Therefore the difference between the aggregate road freight transport demand in a country over two years is explained by five factors —C^1, C^2, C^3, C^4 and C^5— which are each individually contained in separated lines of equation **(4)**.

The first term, C^1, captures how much of the increase or decrease in tonne-kms can be attributed to changes in RFTI values in the economic sectors. The second component, C^2, is the "production linkages effect", and shows the effect on the aggregate road freight transport volume of the different use of inputs in the production processes between the years 0 and 1. This effect is caused by technological changes in the economy. C^3 reflects how changes in the GDP structure modify road freight transport demand –the "GDP structure effect"; and finally C^4 and C^5 quantify the contributions of GDP growth and the changes in import volumes to the increase/decrease in aggregate tonne-kms respectively in a country.

We should point out that our methodological approach can explain the evolution of road freight transport demand derived from a country's economic activity as measured by national IO tables. Our model cannot explain far-reaching shifts in traffic in countries with substantial amounts of cross-country traffic, only the proportion of national and international transport in these countries.

EMPIRICAL APPLICATION. SDA OF FREIGHT TRANSPORT DEMAND OF EUROPEAN UNION COUNTRIES

The empirical application is carried out in nine countries in the European Union —Germany, Spain, France, the United Kingdom (UK), Italy, Finland, Sweden, Portugal and Ireland— using data from 2000 to 2007. We considered these countries to be representative for several reasons: first, they are among the largest in Europe; second, they show notable divergences in road transport trends; and third, some of them have been the target-countries of previous decoupling studies, which allows us to compare and confront our results. Other large European countries were not considered as there is no available data to conduct the analysis described above in the study period.

The information on road freight transport demand —data series of tonne-kms sorted by commodity group in each country— was obtained from Eurostat. Economic data were collected from the Input-Output (IO) tables compiled by the World Input-Output Database (WIOD). This dataset provides the IO tables at real prices in US$ (updated to 2011) according to the national accounts.

The reason for using data until 2007 is twofold: first, the lack of complete information related to sector transport demand by commodity after this year; and second, the intention to avoid the impact of the economic downturn in Europe which might distort the final results.

To homogenize the economic and transport data in an identical disaggregate level, we aggregated the original IO tables into eleven groups representing the main areas of economic activity. This was done based on the commodity groups included in the transport dataset. The following eleven industries are considered: (1) Food, beverage and tobacco, (2) Mining, (3) Textile sector, (4) Wood industry, (5) Paper, printing and publishing, (6) Energy: fuel and power products; (7) Chemistry, (8) Machinery and transport equipment, (9) Manufacturing, (10) Construction, and (11) Services.

Table 1 shows the total percentage of increase/decrease of road transport demand in tonne-kms by commodity group, and the variation in aggregate road transport demand for each country throughout the study period. In this research we explain these changes through the effects described above. Different patterns can be identified at a glance. In most countries the aggregate road transport volume increased, albeit unevenly, with a very wide variability range across this group of countries. However, other countries such as Finland, Italy and the UK had lower road transport volumes in 2007 than in 2000, even with real GDP growing during this period —as we also see in the table—. The question that arises now is what factors really explain these differences and how we can characterise them.

TABLE 1. Variation in road freight transport demand —in % tonne-kms— by commodity group from 2000 to 2007

Sectors \ Countries	DE	ES	FI	FR	IE	IT	PT	SE	UK
Food, beverage &tobacco	+27	+73	-6	+6	+40	-10	+72	+17	-23
Mining	+8	+101	-4	+15	+102	-1	+47	+22	+5
Textile sector	+33	+81	-18	-17	+37	-6	+62	-8	-25
Wood industry	+25	-22	-24	-5	+57	-18	+50	+13	-27
Papers & Printing	+48	+90	-23	-15	+500	-3	+18	-3	+30
Energy goods	-7	+32	+24	+14	+22	+7	+58	-7	-34
Chemical products	+36	+50	-6	-19	+17	-10	+120	-14	-27
Machinery & Transports	+42	+107	+37	-17	+135	-22	+84	+4	-21
Manufacturing	+24	+25	+39	-8	-33	-26	+94	+46	-21
Construction products	-10	+116	+8	+28	+57	+12	+49	+12	-4
Service products	+44	+46	±0	+26	+49	+16	+167	+30	-12
Total	**+24**	**+74**	**-7**	**+8**	**+54**	**-3**	**+73**	**+15**	**-17**
Δ Real GDP	**+74**	**+146**	**+102**	**+95**	**+163**	**+93**	**+103**	**+86**	**+92**

Countries: (DE) Germany, (ES) Spain, (FI) Finland, (FR) France, (IE) Ireland, (IT) Italy, (PT) Portugal, (SE) Sweden, (UK) United Kingdom.

Key factors driving road freight transport trends in Europe

By applying the equation **(4)** we calculated the contribution of the evolution of road transport intensity, production structure, GDP structure, growth in GDP and import volumes on the annual aggregate road freight transport demand for each commodity class. The contributions are measured in % of tonne-kms that road transport volume would increase/decrease due to the isolated effect produced by the change in each variable. By aggregating all sector contributions for all the five components we obtain the total variation in total road freight transport explained by each effect, and finally by aggregating these five contributions we obtain the total change in road freight transport between the base year 2000 and the other years in the study period.

The sectorial results obtained by applying the decomposition expression reveal the most relevant sectors fuelling road transport demand trends by adding or declining tonne-kms in each country. Overall the food, beverage and tobacco sector emerges as being a key explanatory sector in road transport volumes in Europe. It is the largest sector in terms of tonne-kilometres, largely due to the fact that it is linked to long-distance transport, and thus has a higher road transport intensity than others. In most countries the reduction of RFTI for the food, beverage and tobacco sector contributed substantially to the decline in road freight transport demand. This sector has important linkages with other sectors; for instance, it sells inputs to hotels and catering services.

Another sector worth highlighting for its positive contribution to freight transport demand in some countries is the mining sector. This sector is partly driven by the construction industry, which from 2000 to 2007 –before the onset of the recession– grew significantly in countries such as Spain, Portugal and Sweden.

However, despite these common patterns, the main conclusion to be drawn from the results is that there are major asymmetries in the way industries contribute to increasing/decreasing road freight transport volumes across the European countries in the study. This trend is largely dependent on each sector's growth by country, the weight of each sector in the economy, the evolution of sector linkages, and the performance of the supply chain.

As indicated above, the final contribution of each factor explaining road transport demand is obtained as the sum of sector contributions. Figure 1 below shows the aggregate results per country between 2000 and 2007. The graphs show that the growth in both GDP and imports contributed to increasing tonne-kms in all countries. As a consequence of that trend, in Spain, Portugal and Ireland road freight transport volume increased practically uninterruptedly at rates closely matching economic growth, whereas in other countries such as Finland and Italy, road transport remained stable or even declined under economic growth scenarios. This effect is mostly explained by changes in RFTIs, with moderate contributions from sector production linkages and GDP structure effects. The results reveal that all these countries evolved towards economies led largely by non-intensive transport sectors, and most (excluding Portugal) incorporated structural, procedural and logistical changes into their supply chains that caused a sustained decrease in global road freight transport intensity. All told, the most significant decoupling effect took place in the UK, where road transport volume fell by 17% from 2000 to 2007 while its GDP increased by 92% in the same period.

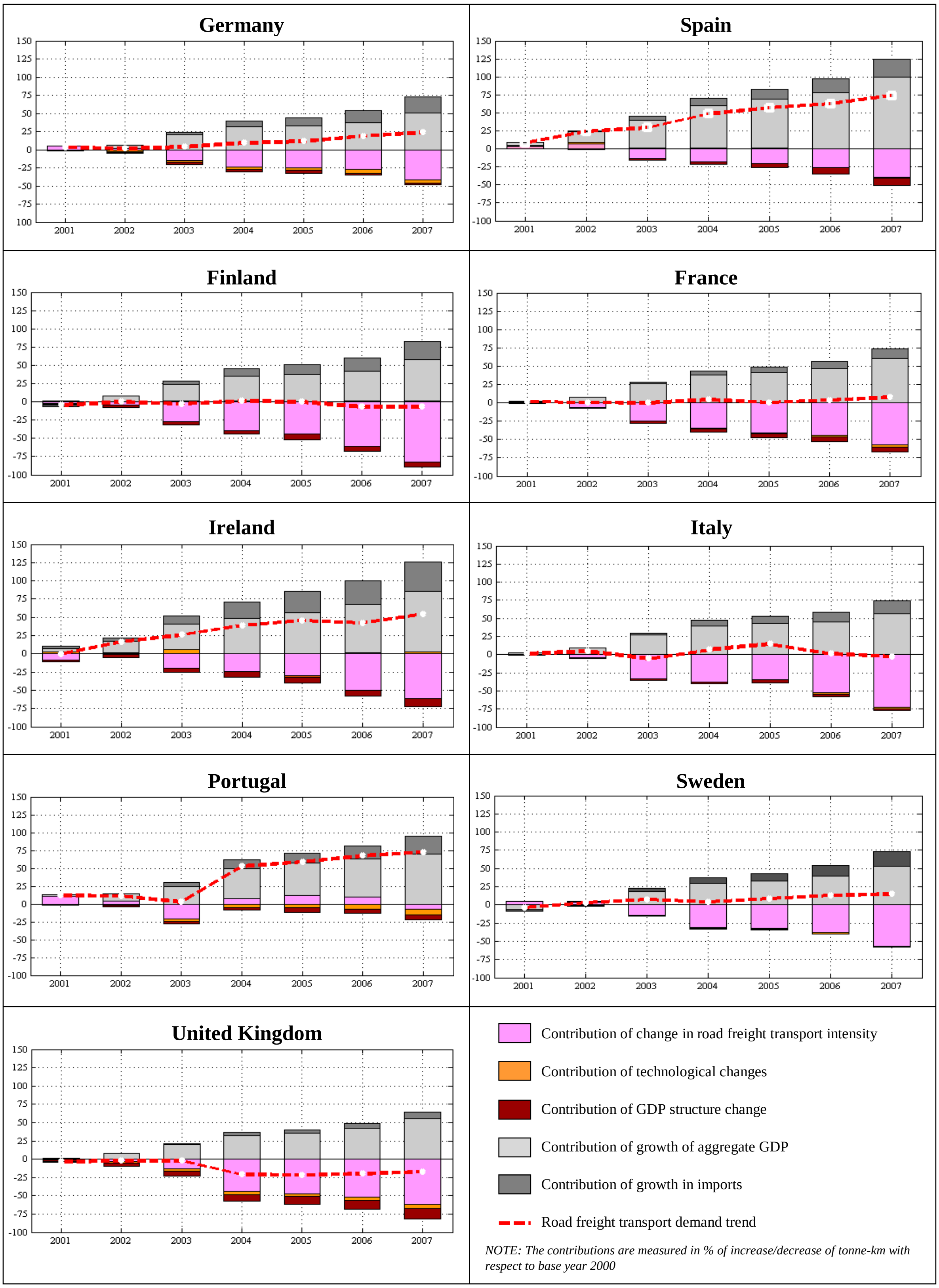

FIGURE 1. Contribution of all effects to changes in road freight transport from 2000 to 2007

It is worth noting that data from Eurostat by commodity class in a country only include freight carried by domestic hauliers. Foreign-registered vehicle activity in a country—cabotage and international transport (both dispatch and receipt) carried by foreign-registered vehicles— is excluded from this type of data series.

However, according to Eurostat series we have verified that this activity can be considered almost negligible since it accounts for only about 1% or 2% of total tonnes lifted in all the case studies. So, this data limitation will barely distort our results.

Analysis of similarities and divergences through a cross-country comparison: : confrontation with previous researches

In 2005, Tapio *(21)* cited a weak relative decoupling between freight traffic (and also for passengers) and GDP during the 1990s in five countries: Finland, Sweden, the UK, Ireland and Luxembourg. By contrast, in the Netherlands and Portugal, he identified an expansive negative decoupling while transport volumes grew at higher rates than GDP. In all the other countries of EU-15, GDP decreased during that decade while transport continued to grow. Tapio emphasized the exceptionally high elasticity values observed in Germany in that period. According to Leonardi, some drivers of that trend were the globalisation and the opening of Eastern European markets. This growth only was absorbed by the road mode due to the low competitiveness of German freight rail *(22)*.

In view of our results, we can provide a classification of our sample of countries based on the degrees of coupling and decoupling of transport volume growth from economic growth given by Tapio in the above mentioned study.

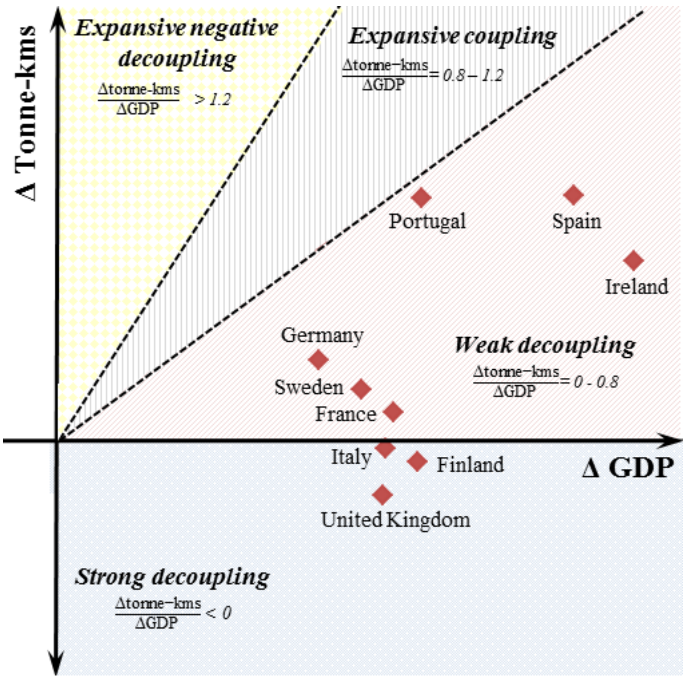

FIGURE 1. Level of decoupling of freight transport volume from GDP in EU countries from 2000 to 2007

We observe that most countries experienced a weak decoupling during last years. However, countries like the UK and Finland, where Tapio noted this situation of weak decoupling in the 90s, have already achieved a strong decoupling level. It is highlighted that other countries, like Portugal and Germany, have evolved from an expansive negative decoupling to a weak decoupling level. However, we observed that Portugal is still very near to the coupling region because its transport volume continues to grow closely to economic growth.

On the basis of the results obtained from the analysis of previous subsection, we can clearly identify groups of countries where some significant factors have strongly promoted decoupling. In order to synthesise all this information, we conduct a cross-country comparison focused on the three first aggregate contributions, which do not depend on national economic growth but on the evolution of structural and logistical features namely: road transport intensity evolution (C^1), production linkages effect (C^2) and GDP structure effect (C^3). These may be influenced in one way or another by structural and good supply' companies decisions and strategies, as well as by some policy measures.We use the value of the total contributions of these factors for each country (graphically represented in Figure 1). By contrasting them with the average value we can classify the countries (Table 2) in terms of their behaviour compared to the average contribution of each factor. In countries above the average, these factors contribute more to increasing road freight traffic and less to decoupling.

TABLE 2. Classification by countries on the basis of their contributions to decreasing road transport demand

$\mathbf{C^1 > C^1_{mean}}$ *(*)*	$\mathbf{C^2 > C^2_{mean}}$ *(**)*	$\mathbf{C^3 > C^3_{mean}}$ *(***)*
Portugal, Spain, Germany	Ireland, Finland, Spain, Sweden, Italy	Sweden, Germany, Italy, Finland
$\mathbf{C^1 < C^1_{mean}}$	$\mathbf{C^2 < C^2_{mean}}$	$\mathbf{C^3 < C^3_{mean}}$
Sweden, France, Ireland, United Kingdom, Italy, Finland	France, Germany, United Kingdom, Portugal	France, Portugal, Spain, Ireland, United Kingdom

(*) C^1 is the contribution of changes in road freight transport intensities

(**) C^2 is the contribution of restructuring in sector production linkages

(***) C^3 is the contribution of GDP structure changes

From this table, we can easily identify the countries that contribute either positively or negatively to decoupling. Finland, Italy and the UK are the countries in which the effect of RFTI evolution was most effective in reducing demand for road freight transport, , and moreover these countries are the three ones that have achieved a strong decoupling (see Figure 2). These countries can be seen to have improved their logistical performance more than others during this period. In contrast, the RFTI evolution in Portugal had an almost negligible effect on reducing road freight transport demand. This last finding is also seen in Figure 1, which shows that this effect even led to an increase in road freight transport in many of the years in the study period compared to the base year 2000.

Table 3 shows the aggregate values of RFTI (total tonne-kms/total output) for each country in 2000 and 2007 together with the variation occurred in each one of them.

TABLE 3. Road freight transport intensity [tonne-kms/output] values and variation between 2000 and 2007 by country

Country / Year	DE	ES	FI	FR	IE	IT	PT	SE	UK
2000	0,080	0,135	0,136	0,084	0,060	0,086	0,125	0,069	0,077
2007	0,054	0,091	0,061	0,046	0,034	0,043	0,107	0,042	0,033
Δ RFTI	-32%	-32%	-55%	-45%	-42%	-51%	-14%	-39%	-57%

Based on the conceptual framework develop by Mckinnon *(9)* that illustrates the way RFTI is defined through the key ratios already mentioned in section 2—value density, handling factor, modal split and length of haul— we can give some explanations of the different patterns followed by different countries.

It is clear that after 2004 RFTI clearly contributed to reduce road transport in the UK (see Figure 1). In this country Lethonen identified in 2006 clear decoupling trends in the UK during 1990s and provided a list of reasons of this situation by developing a decomposition analysis of road freight transport into different factors *(23)*. He found that after this year the shortening of the average length of haul seemed to begin to influence decoupling. During previous decades, the increase of the average length of haul was identified as the main factor contributing to increase road transport *(6)*, partly due to the concentration of the economic activity. However, the new trends pointed out by Lehtonen suggested that such long-established concentration of production and inventory was beginning to weaken. It could be also caused partly by the outsourcing of delivery processes to large companies managing warehouses in many areas.

By contrast, in the case of Finland, *(24)* found that haulage lengths tended to increase in this country so the growth of value density in all sectors appeared to be the main reason for the decreasing road freight transport intensity between 1995 and 2010. This trend is similar to the one found in Swedem between 1999 and 2008 *(25)*. This explains our results regarding the negative contribution of RFTI to Swedish road freight transport. In these cases, to foster decoupling value densities could have been increased by processes such as the miniaturization of products, the increasing quality of goods or the trend to use lighter materials.

As noted earlier, the contributions —C^2 and C^3— of the other two factors did not have such significant impacts as the evolution of RFTI on the reduction of tonne-kms. However, considerable road freight transport decreases can be seen in cases such as the UK, Ireland and Spain, mainly due to the GDP structure effect (see Figure 1).

In numerous developed countries there has been a movement towards service-oriented rather than manufacture-oriented economies. Here we can highlight the UK, where the share of the service sector of the economy began to rise in the mid 1990s, until reaching a peak of 70% in 2007. In this country, Lethonen *(23)* had already found a declining share of GDP of manufacturing about 27% between 1989 and 2004 leading to less transport demand. In contrast, this trend was not noted in countries such as Sweden and Germany, since transport intensive sectors such as mining and machinery rose rapidly over this period together with service activities. As a result only minor road transport decreases were caused by the restructuring of the GDP.

Finally, the effect of production linkages in Portugal, United Kingdom, Germany and France is significant compared to the average. This signals that these countries changed their production processes, either by implementing technological innovations or by substituting inter-sector relationships and these changes reduced the dependence of their production on exchange of goods and therefore on road freight transport. In contrast, Ireland and Finland are examples of the opposite trend as their production processes required a growing amount of tonne-kms, as seen in Figure 1.

CONCLUSIONS

EU countries reveal different rates of decoupling. This issue that has received considerable attention in the literature as it is viewed as an opportunity to promote sustainable development. In this paper we have developed a new methodology to go as step further in understanding both the key factors driving road freight transport trends in Europe at the macro level and the differences between countries. Thus, we have connected all the influencing variables on road transport: economic indexes —production, economic structure, intersectoral dependence, imports or exports — and technological and logistic factors. On the basis of the implementation of the methodology to nine European countries, we can give several conclusions. Firstly, we have identified the main coupling and decoupling factors in Europe during last years. In this respect, we have found that the evolution of GDP and imports in Europe has contributed to increasing road freight transport demand. This is only reasonable in view of the fact that the greater the economic activity and trade, the higher the freight transport volumes. The positive decoupling trends observed can be explained, as a whole, by (1) technological changes— that are prompting new sector linkages in production processes that require less exchange of goods— (2) the transition to more service-oriented economies has also led to a decline in road freight traffic; and (3) the pursuit of transport efficiency —which has been measured through the road freight transport intensity (RFTI) ratio.

Particularly, we have noticed the effectiveness of RFTI evolution in decreasing final road freight transport demand in most countries. This ratio includes different aspects such as the average distance of the trips —based on the geographical location of production and consumption poles—, the structure of the supply chain, the management of the transport system, and the evolution of the modal split. In this paper, we have provided a first overview of the similarities and divergences of the contributions of global values of RFTIs in road freight transport trends through a macro-analysis. Our results show that the evolution of the factors explaining RFTIs in the EU countries is diverse and cause different impacts in countries' road freight transport trends. Previous research works mentioned in this paper pointed out some similar patterns like the negligible contribution of modal split on development of transport intensity, or the spatial concentration of production and inventory in most developed countries.

However, despite the fact that we have highlighted some possible reasons such as the shortening of the haulage distances in the UK or the increase in the value densities of Finnish goods, further analysis based on a micro approach would be necessary in order to improve the understanding of the mechanisms underlying RFTI trends in each country.

In the light of the cross-country comparison developed, we can confirm that Europe as a whole seems to be on the path to decoupling without compromising economic growth. Six out of the nine countries analysed —Sweden, France, Ireland, Portugal, Spain and Germany— experienced weak decoupling from 2000 to 2007. The UK, Ireland and Finland have even reached a strong decoupling level during this time. Looking more in detail at the contribution of different decoupling factors, we notice that in just these three countries RFTI has had the most notable effect in decreasing road freight transport demand. This proves the relevance of such a variable in breaking the link between road transport and the economy. RFTI performance has been almost negligible in Portugal and as a consequence of that, this is the country nearest to a coupling situation.

Finally, our research has revealed that most countries have continued seeing greater decoupling levels than found in previous research. This suggests that, if the current trends in the economy and in the manufacturing and logistical industry continue, road transport is likely to keep on decoupling from GDP at the EU-level, as already is happening in countries like the UK. However, Europe still has room for improving other measures such as the shift of freight transport from road to alternative more environmentally-friendly modes. Some decoupling policies aimed at promoting such changes would further strengthen the sustainable mobility in the EU.

Actually, little research focused on to the effectiveness of "decoupling policies" has been undertaken. Thus, going further into this issue could be essential to achieve the promotion of decoupling required in the EU transport systems.

References

1. European Commission. *A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development (Commission's proposal to the Gothenburg European Council)*. 2001.

2. European Commission. *Freight Transport Intensity of Production and Consumption*. Spain, 2003.

3. OECD. Decoupling the Environmental Impacts of Transport from Economic Growth.

4. European Commission. *European Transport Policy for 2020: Time to Decide [COM(2001)370]*. 2001.

5. Ballingall, J., D. Steel, and P. Briggs. Decoupling economic activity and transport growth : the state of play in New Zealand. *26th Australasian Transport Research Forum Wellington New Zealand*, 2003.

6. NEI. *REDEFINE: Relationship between Demand for Freight-transport and Industrial Effects*. 1997.

7. Standing Advisory Comittee on Trunk Road Assessment-SACTRA. Transport and the economy : full report (SACTRA). *Transport and the Economy.*, 1999.

8. OECD. Analysis of the Links Between Transport and Economic Growth. http://www.oecd.org/general/searchresults/?q=Analysis of the Links Between Transport and Economic Growth&cx=012432601748511391518:xzeadub0b0a&cof=FORID:11&ie=UTF-8.

9. McKinnon, A. C. Decoupling of Road Freight Transport and Economic Growth Trends in the UK: An Exploratory Analysis. *Transport Reviews*, Vol. 27, No. 1, Jan. 2007, pp. 37–64.

10. Lehtonen, M. Energy use in UK road freight : a literature review. August. 1–84.

11. Åhman, M. *A Closer Look at Road Freight Transport and Economic Growth in Sweden A Closer Look at Road Freight Transport and Economic Growth in Sweden Are There Any Opportunities for Decoupling ?* Sweden, 2004.

12. McKinnon, A., and A. Woodburn. Logistical restructuring and road freight traffic growth. *Transportation*, Vol. 23, No. 2, May 1996.

13. Cascetta, E., G. Conigliaro, and M. Di Gangi. A Multi-Regional Input-Output Model with Elastic Trade Coefficients for the Simulation of Freight Transport Demand in Italy. *PTRC EUROPEAN TRANSPORT*, 1996.

14. Alcántara, V., and R. Duarte. Comparison of energy intensities in European Union countries. Results of a structural decomposition analysis. *Energy Policy*, Vol. 32, No. 2, Jan. 2004, pp. 177–189.

15. Wachsmann, U., R. Wood, M. Lenzen, and R. Schaeffer. Structural decomposition of energy use in Brazil from 1970 to 1996. *Applied Energy*, Vol. 86, No. 4, Apr. 2009, pp. 578–587.

16. Chang, Y. F., and S. J. Lin. Structural decomposition of industrial CO2 emission in Taiwan: an input-output approach. *Energy Policy*, Vol. 26, No. 1, Jan. 1998, pp. 5–12.

17. Guti, S. Economic activity and atmospheric pollution in Spain : an input-output approach. No. September, 2008.

18. Leontief, W. Quantitative Input-Output Relations in the Economic System of the United States. *Review of Economics and Statistics*, Vol. 18, 1936, pp. 105–125.

19. Eurostat. “Eurostat Manual of Supply , Use and Input-Output Tables 2008 edition”. 158.

20. Dietzenbacher, E., and B. Los. “Analyzing Decomposition Analyses”. *András Simonovits and Albert E. Steenge (eds.), Prices, Growth and Cycles*, 1997, pp. 108–131.

21. Tapio, P. Towards a theory of decoupling: degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. *Transport Policy*, Vol. 12, No. 2, Mar. 2005, pp. 137–151.

22. Leonardi, J. Understanding CO 2 reduction and efficiency in road freight transport and logistics . German surveys and case studies 2002-2005. 2006.

23. Lehtonen, M. Decoupling freight transport from GDP – conditions for a “ regime shift ”. 2006.

24. Liimatainen, H., and M. Pöllänen. The impact of sectoral economic development on the energy efficiency and CO2 emissions of road freight transport. *Transport Policy*, Vol. 27, May 2013, pp. 150–157.

25. Eng-Larsson, F., K.-J. Lundquist, L.-O. Olander, and S. Wandel. Explaining the cyclic behavior of freight transport CO2-emissions in Sweden over time. *Transport Policy*, Vol. 23, Sep. 2012, pp. 79–87.